Incidental Recharge in the Lower Flint River Basin:

Agricultural Irrigation and Consumptive Use

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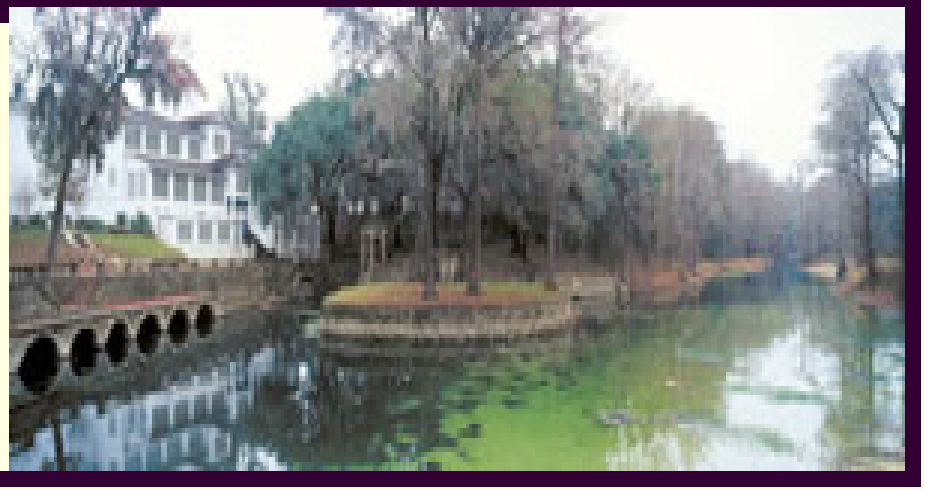


Radium Springs, Albany GA

Introduction

- Draws on research in hydrology, agronomy, and agricultural / irrigation engineering
- ***Recharge*** refers to the replenishment of water to aquifer.
- **Incidental recharge** is water that reaches the water table after human use, such as agricultural irrigation
- This has crucial implication for water planning and permitting in the state.

Incidental Recharge

- Is a critical component of every irrigation scheduling and/or water balance equation
- Regarded as “loss” when calculating irrigation quantities for crops
- Will be equated with deep percolation in the model for project
- A difficult process to quantify.

Purpose and Scope

- To present a more accurate accounting of the state's water resources
- To quantify how much of the water utilized for irrigation is returned to the system via deep percolation (incidental recharge)
- Estimate actual consumptive irrigation use of water in the Flint basin

Significance

- Significantly improve the manner in which water policy is designed
- Facilitate more accurate accounting for the permit issue and renewal
- Facilitate the development of a complete water budget for the state.

Definitions

- **Water Holding Capacity**- Soil texture and structure (actually the pore space created by soil texture and structure) primarily determine a soil's ability to hold water. Water coats the soil particles and organic matter and is held in the small pore spaces by cohesion (the chemical forces by which water molecules stick together). Air fills the large pore spaces. Water readily moves downward by gravitational pull through the large pore spaces. In small pore spaces, water moves slowly in all directions by capillary action.

- **Recharge-** is the replenishment of an aquifer with water from the land surface. It is usually expressed as an average rate of millimeters of water per year, similar to precipitation. Thus, the volume of recharge is the rate times the land area under consideration, and is typically expressed in millions of cubic meters per year.

- **Available Soil Moisture**-is the amount of the water held in a soil between field capacity and the permanent wilting point. This represents the quantity of water available or usable by the plant.

- **Permanent Wilting Point**-refers to the situation when a plant wilts beyond recovery due to a lack of water in the soil. At this point the soil feels dry to the touch. However, it still holds about half of its water, but the plant just does not have the ability to extract it. Plants vary in their ability to extract water from the soil.

- **Evapotranspiration**-is the rate a crop uses water for transpiration plus evaporation from the soil surface. Primary influences on ET include weather factors (solar radiation, temperature, wind, and humidity) and the stage of plant growth.

- **Consumptive Use**- Consumptive water use refers to water that is not returned to streams after use. For the most part, this is water that enters the atmospheric pool of water via evaporation (from reservoirs in arid areas) and from plant transpiration

- **Incidental Recharge**- Incidental recharge is water that reaches the water table after human use. The amount of incidental recharge depends mostly on the extent and water use efficiency of certain human activities, such as irrigated agriculture, mining and the discharge of effluent into stream channels

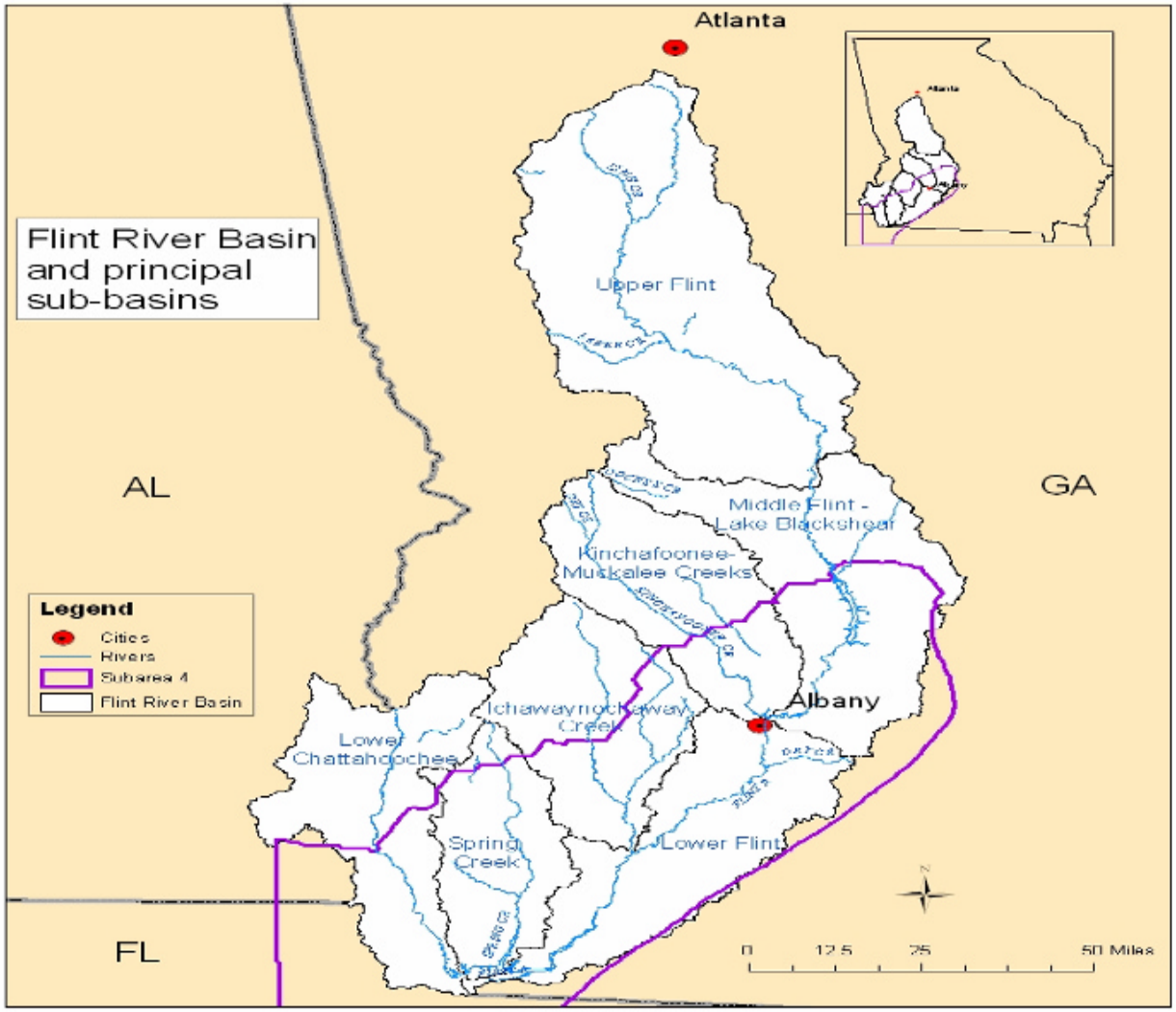
Georgia – State Facts

- Climate: humid, subtropical
- Ave temperature ~80ºF (July), 45ºF (Jan)
- Annual Precipitation:
  - Rainfall: about 51 ins
  - Snow: 0.9 ins.
- Relative Humidity (daily) 71%
- Ave days with appreciable precipitation : 131
- Farm products account for close to ¼ of state's overall budget
- Crops represent 38% of far m products

The Lower Flint River Basin

- The study area for this project encompasses 14 counties in the Lower Flint River Basin in South-West Georgia:
  - Baker, Calhoun, Crisp, Decatur, Dougherty, Early, Lee, Miller, Mitchell, Seminole, Sumter, Randolph, Terrell and Worth
- Houses over 1.2 millions acres of designated crop land
- Lies in the Southern Coastal Plain of Georgia
- Experiences in excess of 90 days with temperatures over 90ºF every year
- Has frequent temperature highs over 100ºF
- Average of 51 inches of rainfall every year

The Flint River Basin



Agriculture

- Though barley, rye, silage, sorghum, oats and soybeans are grown in the basin, agriculture is dominated by cotton, corn, peanuts, tobacco and to a lesser extent wheat, straw and hay.
- Study will focus on three most widely cultivated: Cotton, Corn and Peanuts

Irrigation

- USDA/ERS estimated that about 61.9 million acres (crop and pasture) were irrigated in the US accounting for 153 *maf* (close to 40%) of overall freshwater withdrawals.
- For the state (GA): irrigated 1.5 million aces, utilized 1.2 *maf* of water with 439 *maf* (surface withdrawals) and 841 *maf* (groundwater withdrawals)
- There are little data available on actual agricultural water use in the Lower FRB and permits are only required if 100,000 gallons or more are used.
- Four main methods: surface, sprinkler, micro and subsurface

Why Irrigate?

- Irrigation is necessary because of
  - Water has been shown to be the most significant environmental and climatic factor in predicting crop yield
  - spatial, temporal and uneven distribution of the rainfall
  - The “poor” moisture-holding capacity of the light textured (predominantly sandy and sandy-loam) soils in the Coastal Plains

Modeling Approach

- Estimates of incidental recharge to ground water can be done using one or a combination of the following physical methods:
  - Empirical methods
  - Water-balance methods
  - Numerical modeling methods
- A soil-water balance approach

The Soil-Water Balance

- **Advantages**:
  - It utilizes readily available data (rainfall, water levels etc)
  - It is relatively easy to apply
  - It accounts for all the water entering the system
- **Disadvantages**:
  - Recharge is difficult to quantify and is usually estimated as the remainder of all the other hydrological components in the water-balance equation.

Balancing the Checkbook

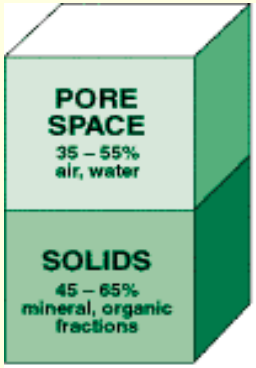
- The soil-water equation can be viewed as a checking account:
- How much money do I have to deposit this week (what are my inputs)?
- How much money do I have in my account: (how much water is available in the soil)?
- How much do I need to spend (what is the crop water use)?
- How much do I have left – to transfer to my savings account (storage)?

Soil-Water Balance *con't*

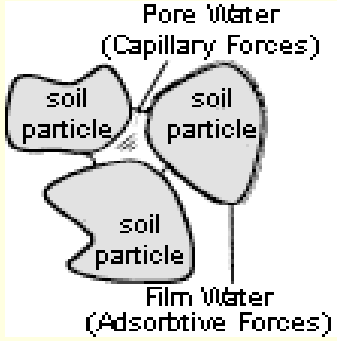
- **Inputs**: rain, irrigation, ground water contributions,
- **Outputs**: Evapotranspiration, surface runoff, spray and drift losses,
- **Storage**: available water (soil-moisture storage), deep percolation (incidental recharge)
- In reality, it is far more difficult because many of these processes are elusive and difficult to model, much less calculate.

Scientific Background

- Soil is made up of bulk and pore spaces, and the percent varies but is typically between 35 and 55 %.

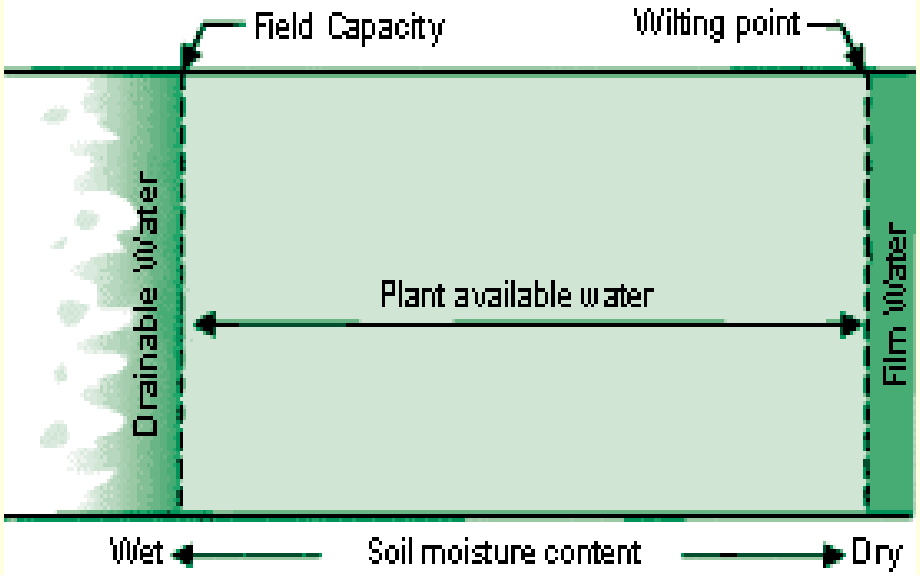


- Water is held in the soil by two methods :
  - Capillarity
  - Absorption



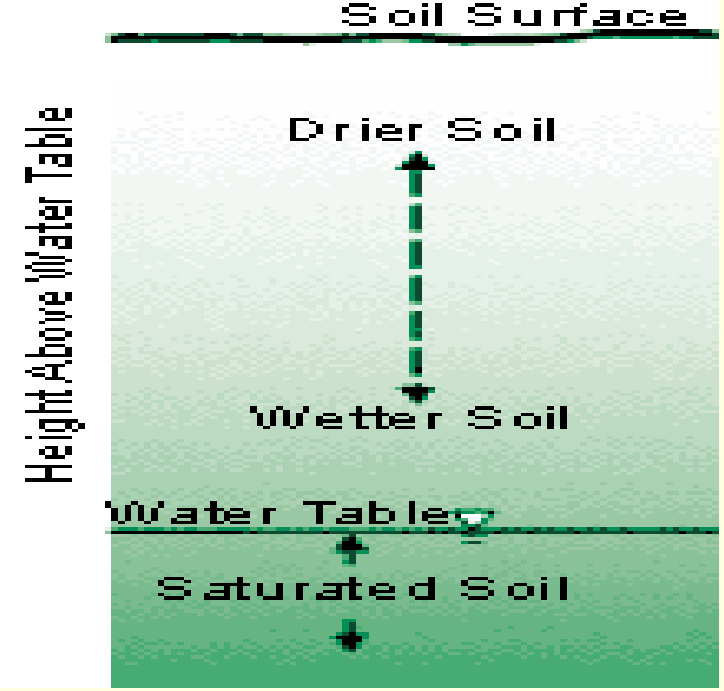
Scientific Background *con't*

- The difference of water in the soil between "field capacity" and "wilting point" is the "plant available water".



Soil Moisture Profile

- Soils must be at field capacity before deep percolation can begin

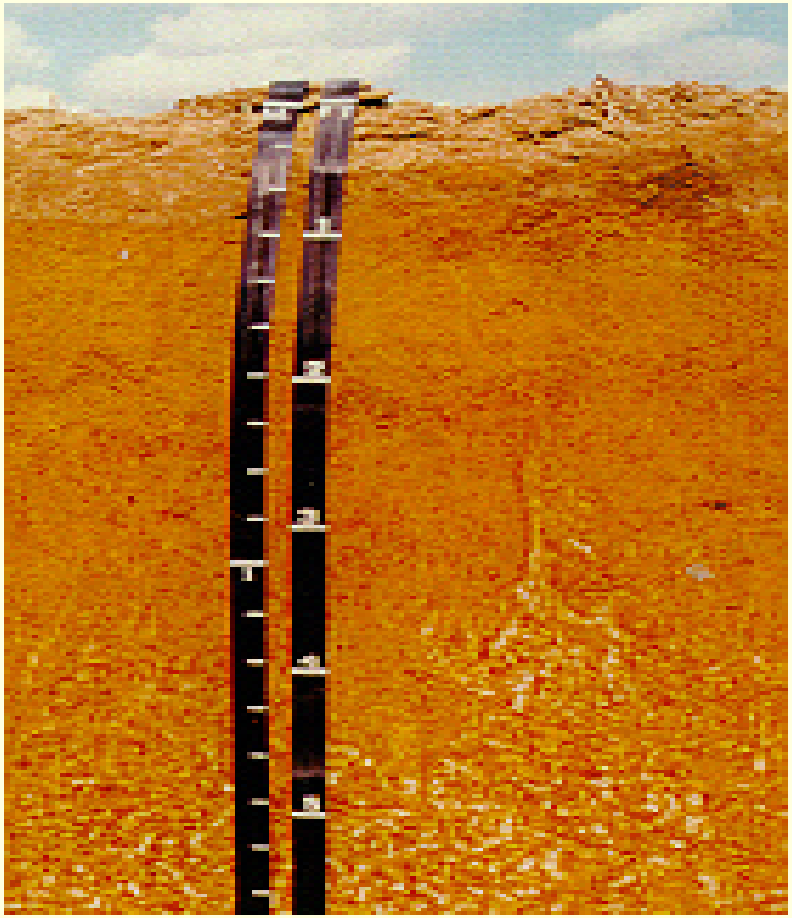


Soils in South West Georgia

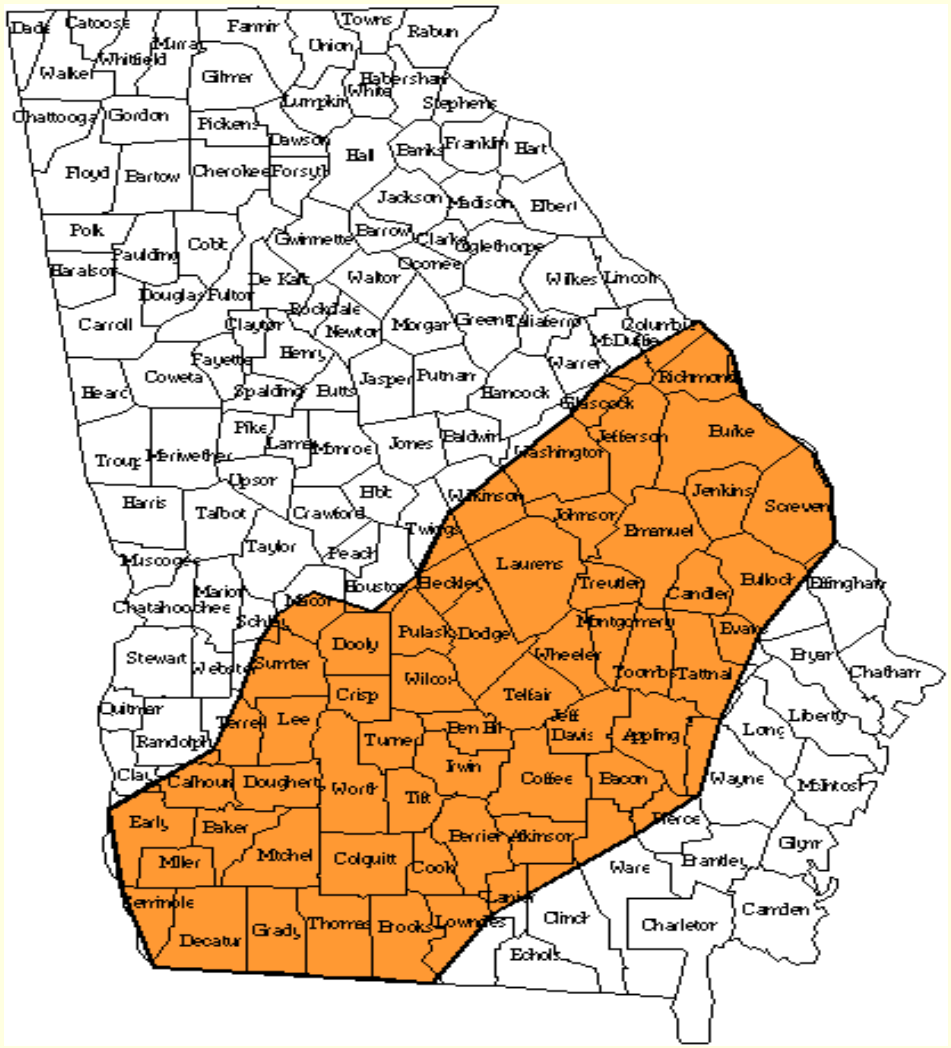
- The soils most prevalent in the growing area are Tifton Soils (NRCS 2006). A typical profile follows:
- Top Soil (to 11”): Loamy Sand
- Sub Soil (to 22”): Sandy Loam
  (to 40”): Sandy Clay Loam (yellow)
  (to 60): Sandy Clay Loam (brown)
  (to 65”): Sandy Clay

Tifton Soil Series Profile

LOAMY SAND (Dark, grayish-brown)	**11 inches**
SANDY CLAY LOAM (Yellowish-brown)	**18 inches**
SANDY LOAM (Strong, brown fine)	**11 inches**
SANDY CLAY LOAM (Strong brown mottled)	**20 inches**
SANDY CLAY	**5 inches**



Location of Tifton Soil Series in GA



Soil-water balance in a crop root zone

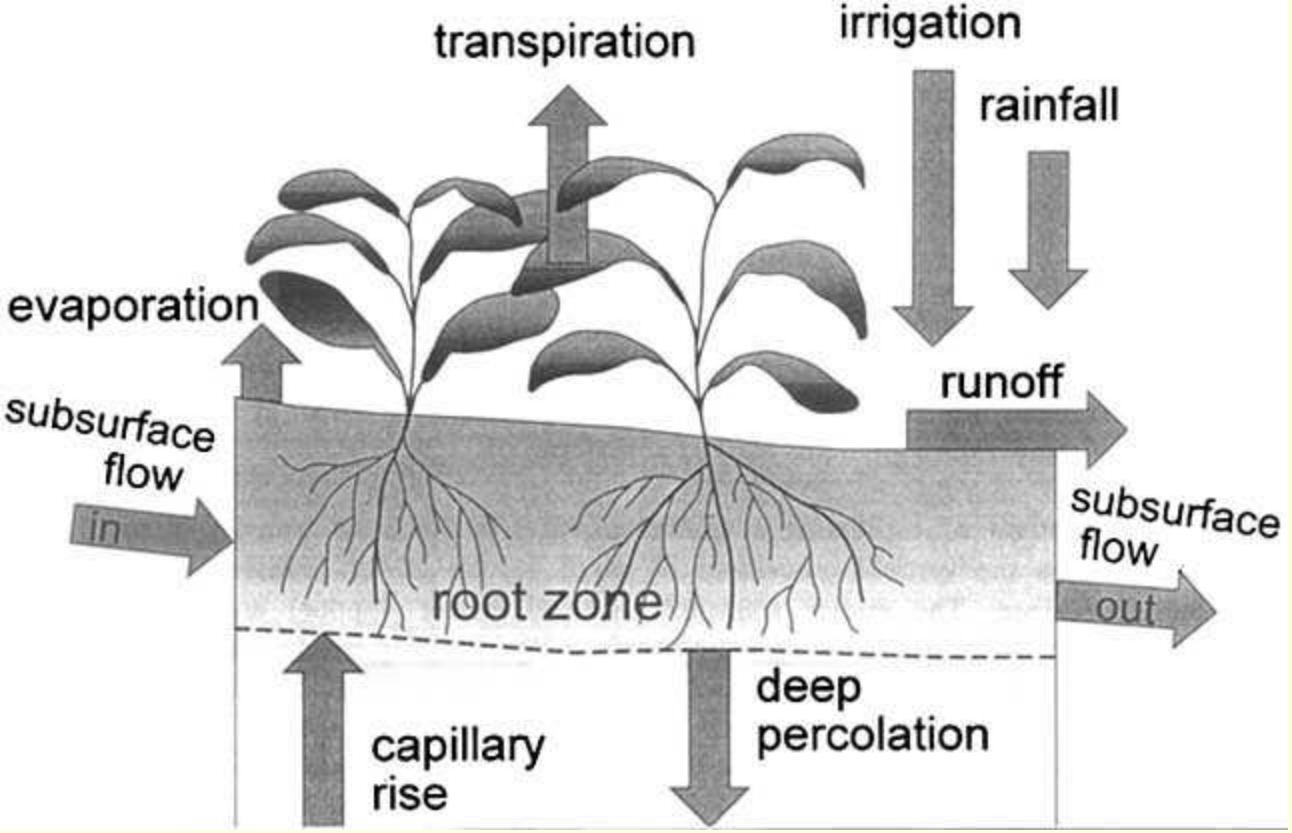
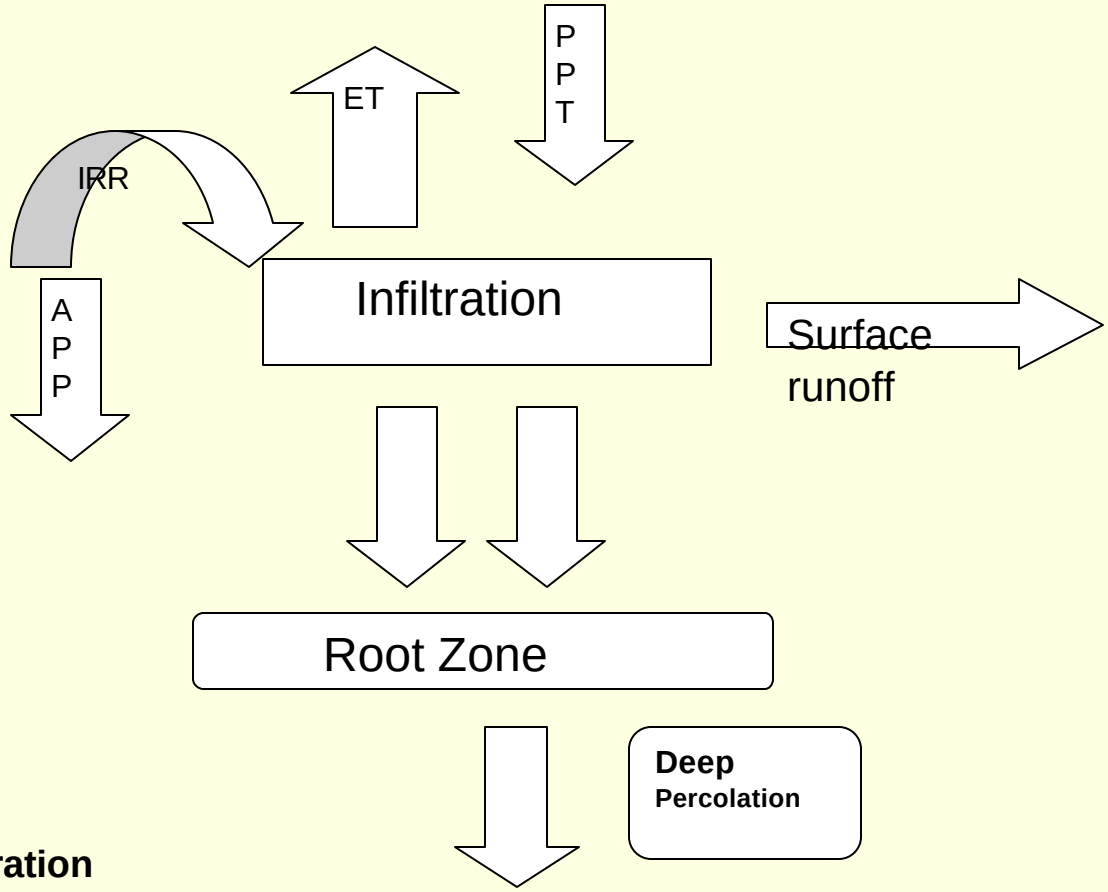


Image Courtesy

www.fao.org/docrep/ X0490E/x0490e06.jpg

Conceptual Model



ET- Evaporation-Transpiration
PPT- Precipitation
IRR-Irrigation
APP- Application Loss

Model

The general Soil-Water Balance Equation can be written as:

$$F_g = Et_c + D_p + RO - P - GW + SD_L - ?SW$$

Where:

Fg = gross irrigation required during the period

Et_c= amount of crop evapotranspiration during the period

D_p = deep percolation from the crop root zone during the period

RO = surface runoff that leaves the field during the period

P = total precipitation

GW = ground water contribution to the crop root zone during the period

SD_L = spray and drift losses from irrigation water in air and evaporation off of plant canopies

?SW = change in soil water in the crop root zone during the period

Model con't

- **Rearranging the terms of the original equation:**

$$D_p = F_g - Et_c - RO + P + GW - SD_L + ?SW$$

Components of Model

- **F_g**: Gross Irrigation (Data are available from EPD, UDSA, Power company records)
- **RO**: in the model represents surface runoff. maybe negligible for irrigation, but will be calculated for precipitation events
- **P -** precipitation (actual)
- **GW**: ground water contributions – would be negligible, and its effects can be ignored in this study

Components of Model (con't)

- **SD_L** : spray and drift losses, function of the application efficiency of the irrigation system.
- **?SW**: change in moisture storage (available water in the root zone)
- **Et_c** : Crop evapotranspiration

$$Et_c = K_c\, ET_0$$

  - Where K_c is the calculated crop coefficient
  - And ET_0 the potential ET

Available Water in the Root Zone

- Relationship between effective root depth and the water holding capacity of the soil
- Water accessible to the plant
- Total amount of water between field capacity and wilting point.
- Calculated as:

  water holding capacity of the soil **x** ***soil depth*** (to the depth of the effective root zone of the plant)

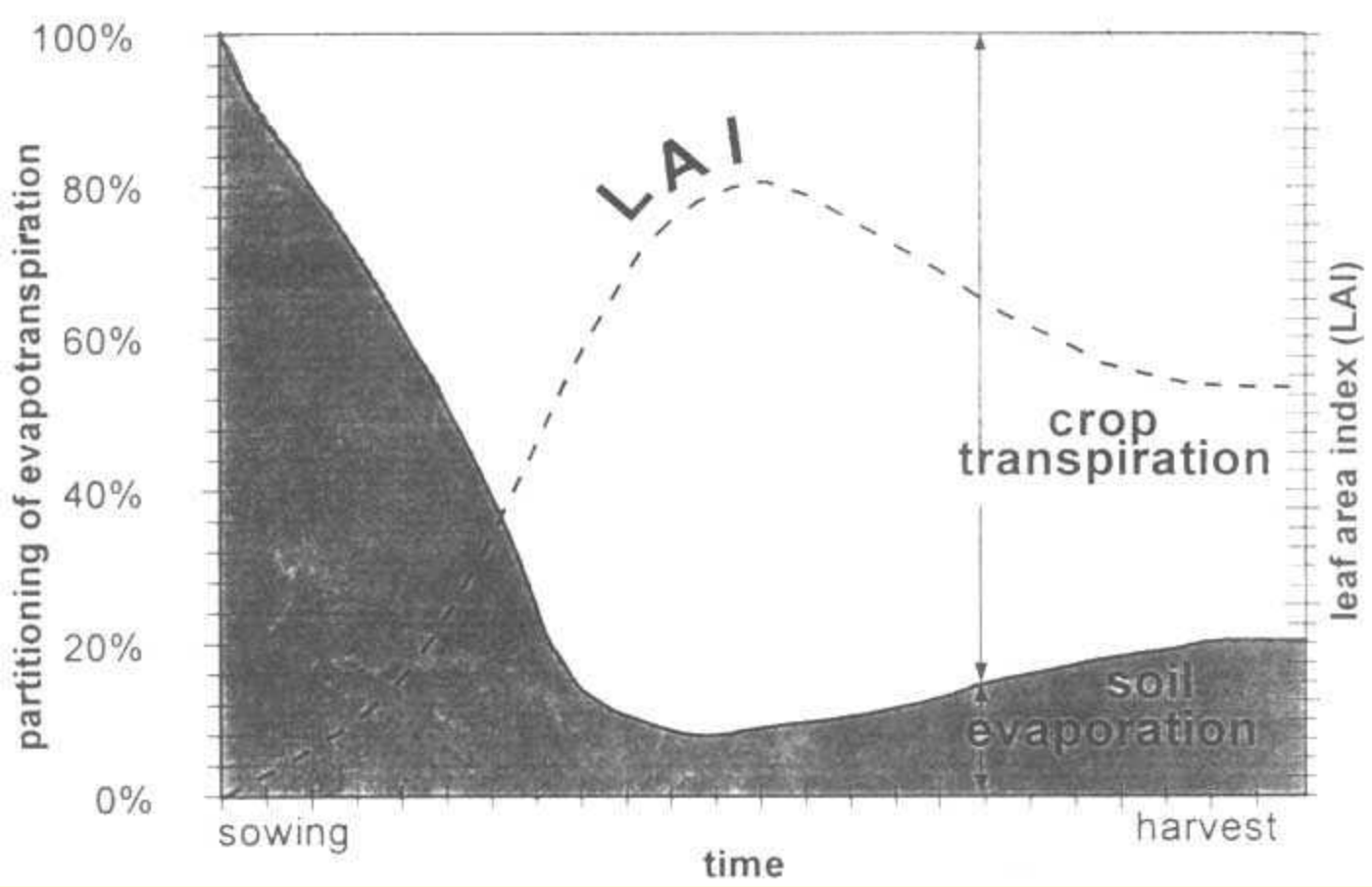
Evapotranspiration

- **ET_0** is a combination of transpiration from a crop and evaporation from the soil)
- It measures the loss of water vapor from both the plant and the surface of the soil
- It's usually the largest outward flux in a water budget and $ET \propto E$,
- There are several methods to calculate namely: pan-evaporation, Penman-Monteith (best for humid areas), radiation, Blaney-Criddle.
- It can also be estimated from remotely sensed images (IR images) or measured directly using lysimetry.
- Data may be also be available from NOAA and/or Georgia Automated Environmental Monitoring Network.

K_c (Crop Coefficient)

- Crop evapotranspiration is determined by the amount of energy available to evaporate water.
- The crop coefficient is a function of the:
  - growth of a crop canopy
  - development of a crop canopy (leaf area index – LAI)
- The crop coefficient usually begins small > increases with canopy development until “effective cover date >remains constant for a time >decrease as plant matures and begins to senesce
- The system developed by Doorenbos and Pruitt in 1977 and modified by Howell and others in 1986 divides growing season into 4 stages: initial, canopy development, mid-season, maturation

Evaporation and transpiration over the growing period of a field crop



Crop Water Use

- The actual crop water use (consumptive use) will be calculated using reference ET and the average crop coefficient (averaged over the four stages life of the plant)
- initial, canopy development, mid-season, maturation

Assumptions

- The soil in the study area has maintained its structural integrity
- No structural impediments to the plant root system
- No ‘hardpans” or large impervious areas in the subsurface of the soil
- Any water that infiltrates beneath the root zone is available for recharge

Conclusion

- A general model that should produce relative accurate estimates over an entire growing season
- Incidental recharge will be calculated for each crop (based on area, length of growing season, effective root depth etc).
- Able to use available data for the basin, without too many assumptions.

Feedback

- Questions?
- Comments?
- Suggestions?